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EFFECT OF INTERCONNECTION OF THE ENDS OF A SLIDING
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DEVELOPMENT CENTER WATERVLIET NY L. R S MONTGOMERY
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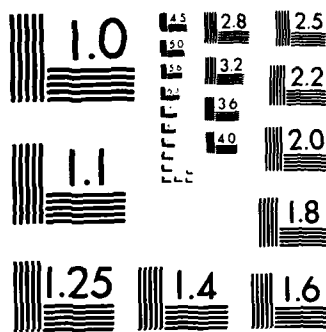
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EFFECT OF THE INTERCONNECTION OF THE ENDS OF A SLIDING BEARING ON FILM THICKNESS

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R. S. MONTGOMERY

SEPTEMBER 1984

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US ARMY ARMAMENT RESEARCH AND DEVELOPMENT CENTER
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The effect of the area of interconnection between the ends of fast-acting bearings such as those of recoil mechanisms used with American tank guns was studied with an apparatus which simulated a concentric recoil system. It was found that these bearings do not "starve" with a small interconnection area, but a larger area would probably produce a faster-acting bearing. It would also result in a thinner fluid film but this would probably be unimportant. (CONT'D ON REVERSE)		

20. ABSTRACT (CONT'D)

The film thickness continues to increase for a time even after the movement of the recoiling tube has stopped, so there appears little chance that the film would entirely collapse before counter-recoil begins. There are two area ratios that result in thinner film thicknesses and slower formation of the fluid film. These area ratios should be avoided. Their locations were at 1.5 and 4.9 mm²/cm but they might be at different locations with the larger actual recoil bearings and with the geometries of specific designs.

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ACKNOWLEDGEMENT

The experimental work reported here was conducted by Mr. Leon J. Szymanski.

INTRODUCTION

In a previous paper on the effect of bearing surface profiles on film thicknesses for sliding bearings such as are used in the recoil systems of American tank cannons (ref 1), the test bearings were made with large "U" shaped grooves running the length of the bearings on the unloaded surfaces. It was conjectured that this would allow the recoil fluid to easily reach the leading edges of the bearings during recoil. Basically, a concentric recoil system consists of two sleeve bearings in which the recoiling gun tube slides, and a recoil fluid reservoir between them. A fluid must flow through a linear sliding bearing at half the relative velocity of the shaft-bearing system for full-film lubrication. The groove in the front bearing would allow the fluid to easily reach the leading edge from the central reservoir. The groove in the rear bearing would allow the fluid to easily return to the central reservoir. Because of the grooves, it was reasoned, fluid would not be forced past the rear seal nor would the front bearing "starve" during recoil.

It is important that an adequate fluid film be formed between the bearings and the gun tube during recoil so that possible scuffing, wear, and the effect of abrasive particles that may have accidentally gotten into the recoil fluid will be minimized. The speed of formation of this fluid film is also important. Since sliding begins from rest, there must be some metal-on-metal sliding until the fluid film is formed but this should be minimized. It is also important that the fluid film not collapse at the end of the recoil

¹Montgomery, R. S., "Effect of Surface Profiles on Characteristics of Concentric Recoil Bearings," Trans. of A.S.L.E., 36, 20 (1977).

stroke so that the counter-recoil stroke will also be fully film-lubricated and friction will be minimum so that the gun will "return to battery".

Upon examination of the literature it was realized that the effect of interconnecting the ends of a sliding bearing on film thickness, especially with the dynamic action of a recoil bearing, was not well known. Therefore, a research program was planned to determine the magnitude of this conjectured effect.

RECOIL SIMULATOR

An apparatus that simulates a tank gun concentric recoil system was used. It was almost the same as that used in the earlier research (ref 1). The only important change was that the load was in an upwards direction with the new apparatus. This better simulated an actual recoil system. This change of course necessitated positioning the film thickness transducer on the bottom of the bearing so that the resting film thickness would be measured as zero (see Figure 1).

A concentric recoil system consists essentially of two sleeve bearings with a fluid reservoir between them and seals outboard of the bearings. The gun tube slides in these bearings lubricated with hydraulic fluid. A general view of the recoil simulator is shown in the photograph in Figure 2. The actual initial recoil load and velocity are very high. The load falls to a low value in just a few milliseconds but the sliding velocity diminishes more slowly only reaching zero at the end of the tube's travel. The test apparatus

¹Montgomery, R. S., "Effect of Surface Profiles on Characteristics of Concentric Recoil Bearings," Trans. of A.S.L.E., 36, 20 (1977).

did not duplicate this behavior of the load. A constant load resulting in a bearing pressure of 240 N/cm^2 (about 350 psi) was applied throughout the sliding test. It was applied with a pneumatic power cylinder having a "nut-cracker" arrangement and measured using a load cell. A closer view showing the arrangement of the bearings, the center reservoir, and the load application point is shown in the photograph in Figure 3. The velocity behavior was closely duplicated by striking the end of the tube with a heavy pendulum and then stopping it with a pneumatic brake. The maximum velocity was about 5 m/s in the experiments. A magnetic proximator probe was used to measure film thickness continuously throughout the experiment. The recoil velocity was measured by means of a linear-variable-differential transformer with the core mounted on the end of the simulated gun tube and the body rigidly mounted on the pneumatic brake assembly. The signal from this device, as well as the signal from the magnetic fluid-thickness probe in the test bearing, was recorded continuously throughout the experiment using a digital oscilloscope.

The bearings were 5.08 cm (2.0 in.) in diameter and 4.14 cm long. This produced a projected bearing area of 42.1 cm^2 for the two bearings. There was a tapered lead-in on the leading edge and a diametral clearance between the shaft and bearings of 0.010 mm. A channel was cut in the top (unloaded side) of the test bearing to obtain different areas of interconnection between the ends. The first series of experiments was made with only the clearance between the shaft and bearing as an interconnection between ends. The interconnection area on only the front bearing was changed in the experiments. After the first series of experiments, the next four interconnection areas

were made by drilling progressively larger holes half in the bearing and half in a plug fitted in the bore of the bearing. The larger interconnection areas tested were made by milling "U" shaped grooves with progressively larger mills. The interconnection areas tested were 1.2, 4.3, 5.2, 7.4, 10.1, 15.1, 20.3, 23.9, 27.9, 33.0, and 41.3 mm². This was 0.24, 0.85, 1.0, 1.5, 2.0, 3.0, 4.0, 4.7, 5.5, 6.5, and 8.1 mm² per cm of bearing diameter. A series of three experiments was made with each interconnection area because of the spread of the film-thickness measurements. The interconnection area was then filled with epoxy resin and the whole process repeated. Three series of experiments were made with the first six ratios, two were made with the next three, and only a single series of experiments was made with the last two. The accent was placed on the smaller ratios because it was felt that they were potentially more important.

RESULTS

The amount of interconnection area between the ends of the bearing greatly influenced both film-thickness and the time of formation of the film. Average film thicknesses, as a percentage of the maximum possible, is plotted in Figures 4 through 7 as a function of the time after impact of the pendulum on the sliding tube. A larger interconnection area results in a thinner film-thickness after 1.0 mm²/cm, but probably a more rapid formation of the film. Unfortunately, the impact of the pendulum causes compressive and reflected tension waves which are reflected back and forth in the sliding tube. This results in erratic velocity measurements from the LVDT for the first four milliseconds after impact. Velocity of the sliding tube as measured by the

LVDT signal is plotted in Figure 8. The initial compressive and tensile waves also cause spurious initial film-thickness measurements from the magnetic probe. Therefore, there is a question about the film-thicknesses for some of the larger areas. There is probably a more rapid formation of the fluid film with the larger interconnection areas but the measured initial maxima probably is not real. The effect of the impact certainly does not extend beyond about seven milliseconds so that film-thickness measurements at longer times would be unaffected.

Film-thickness does not show a single trend with interconnection area. Film-thickness at 16 ms as a function of interconnection area is plotted in Figure 9. The time of 16 ms was arbitrarily chosen to be out of the range of any possible impact effects and to be late enough so that measurements would be indicative of the film-thicknesses obtained with each area. There were two distinct minima, one at about 1.5 and one at about 4.9 mm² per cm of bearing diameter. The film-thicknesses with these areas were low throughout the recoil and not just initially and they were associated with a slower formation of the fluid-film.

CONCLUSIONS

It must be kept in mind that the system investigated was rapidly changing and never reached steady-state operation. There was a high initial velocity and a relatively rapid slowing of the moving tube. Inertial effects were doubtlessly very important. The results obtained with this system would probably not apply to steady-state or more slow-moving systems.

The bearings do not "starve" with a small interconnection area but a larger area would probably produce a faster-acting bearing. It would result in a somewhat thinner film-thickness, but if the thinner film was adequately thick this would be unimportant. The film thickness continues to increase for a time even after the movement of the recoiling tube has stopped so there appears little chance that the film would entirely collapse before counter-recoil begins.

There are two area ratios which result in thinner film thicknesses and slower formation of the fluid film. These area ratios should be avoided. Their locations were at 1.5 and 4.9 mm²/cm, but they might be at different locations with the larger actual recoil bearings and with the geometries of specific designs. In addition, gun tubes expand during firing so that clearances at rest will be much greater than dynamic clearances during firing.

REFERENCES

1. Montgomery, R. S., "Effect of Surface Profiles on Characteristics of Concentric Recoil Bearings," Trans. of A.S.L.E., 36, 20 (1977).

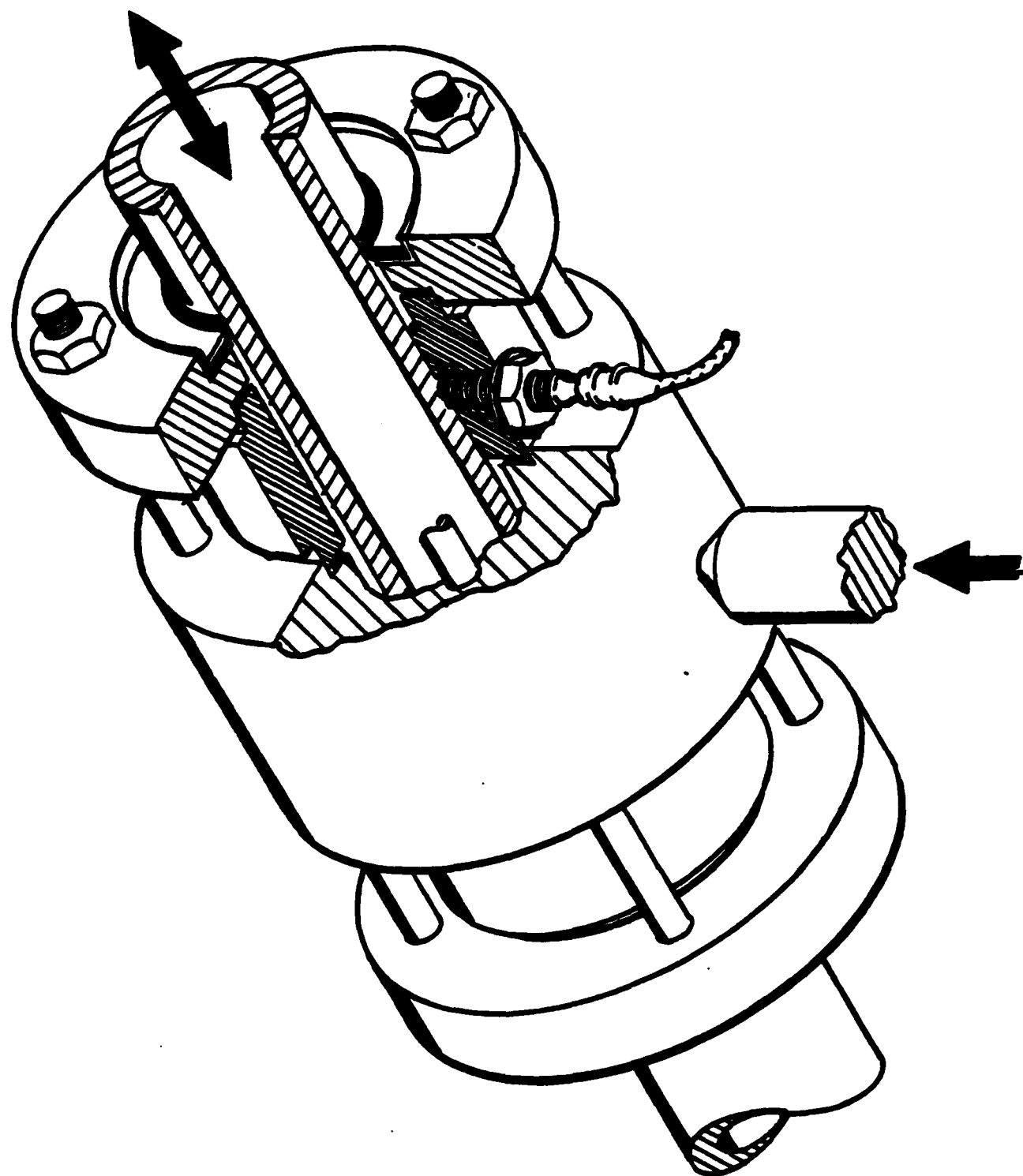


Figure 1. Concentric Recoil Bearing Test Assembly.

- (1) POWER CYLINDER
- (2) PENDULUM
- (3) BEARINGS
- (4) BRAKE
- (5) MAGNETIC VELOCITY PROBE
- (6) LOAD CELL
- (7) CENTER RESERVOIR

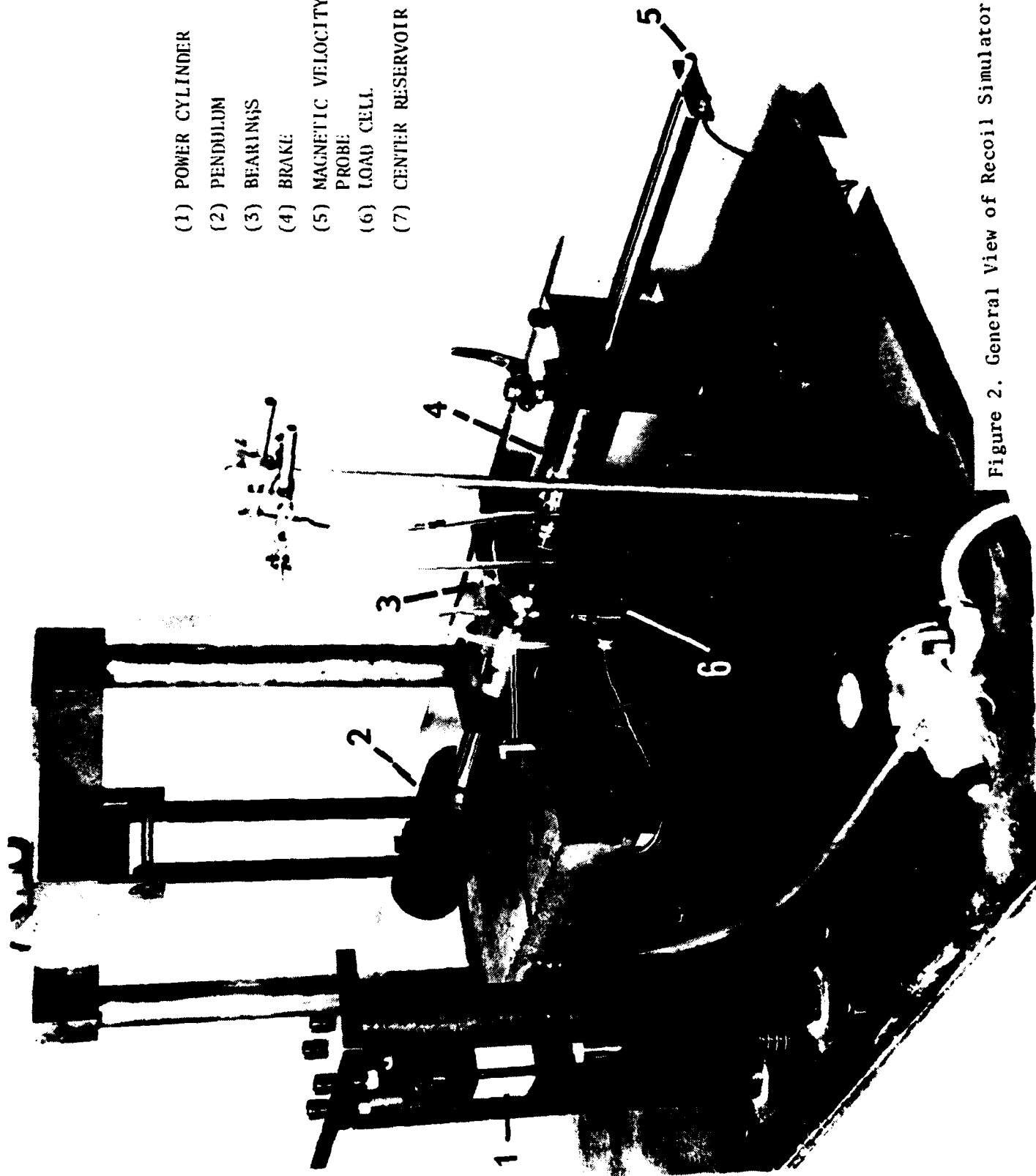


Figure 2. General View of Recoil Simulator.

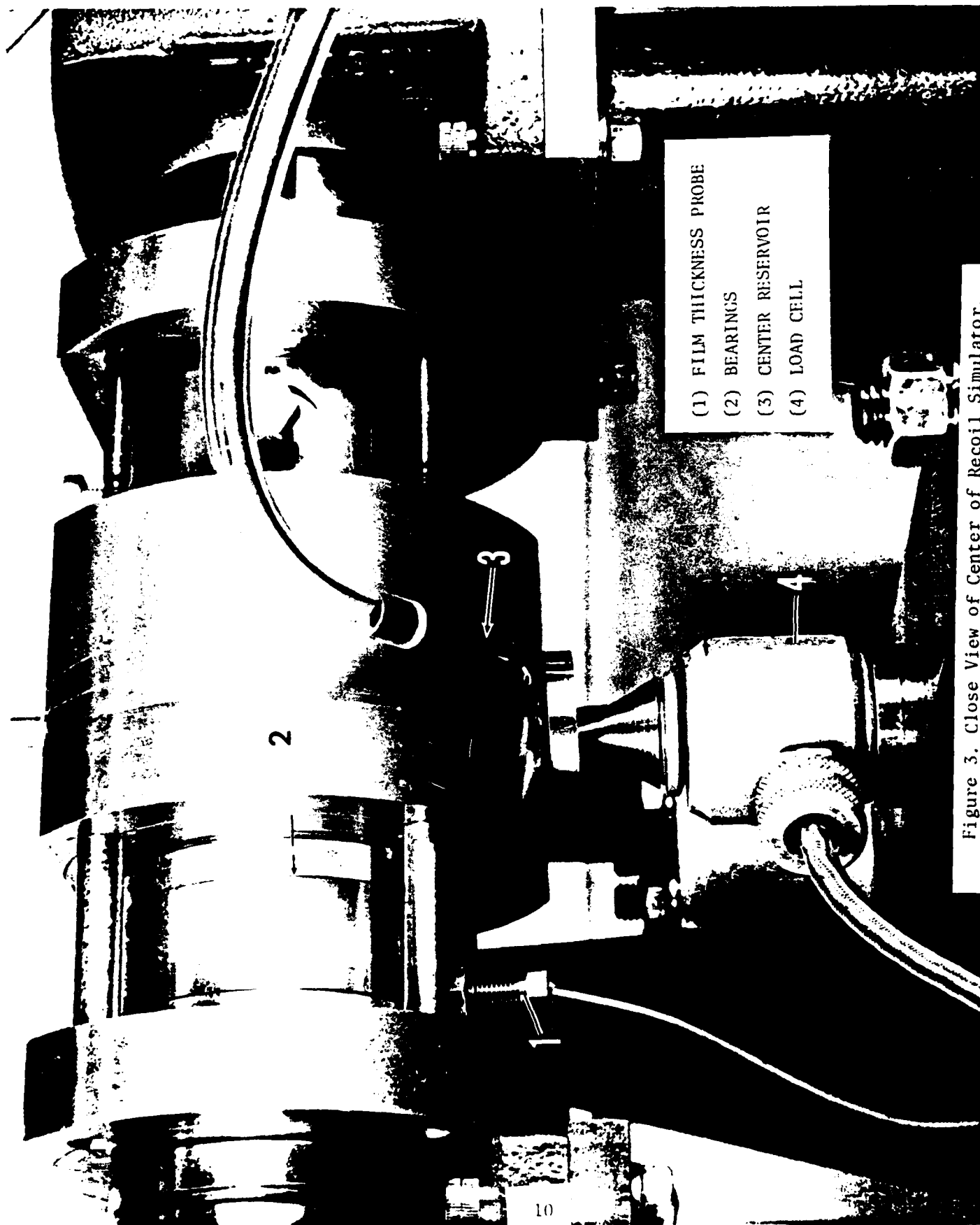


Figure 3. Close View of Center of Recoil Simulator.

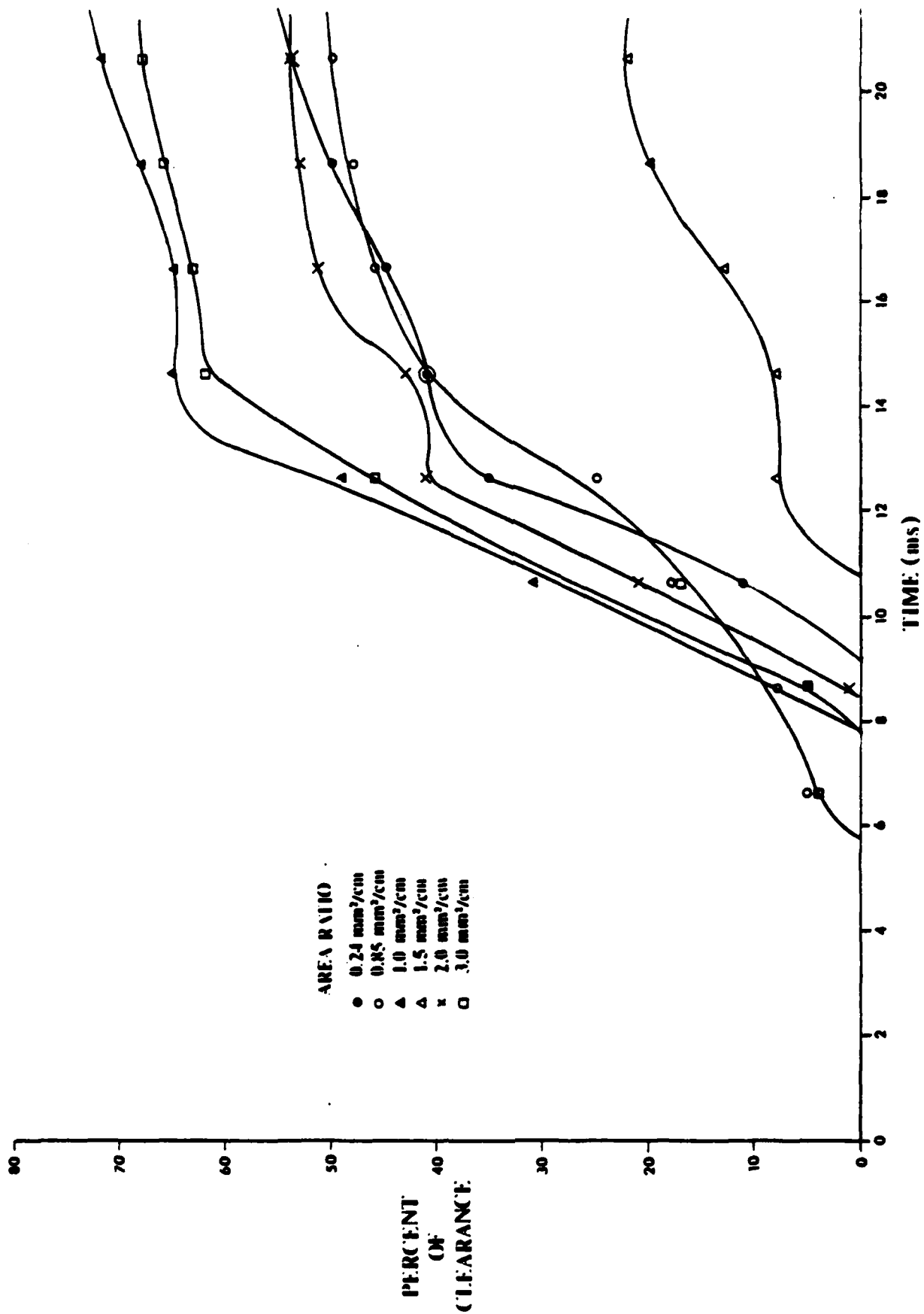


Figure 4. Film-Thickness as a Function of Time.

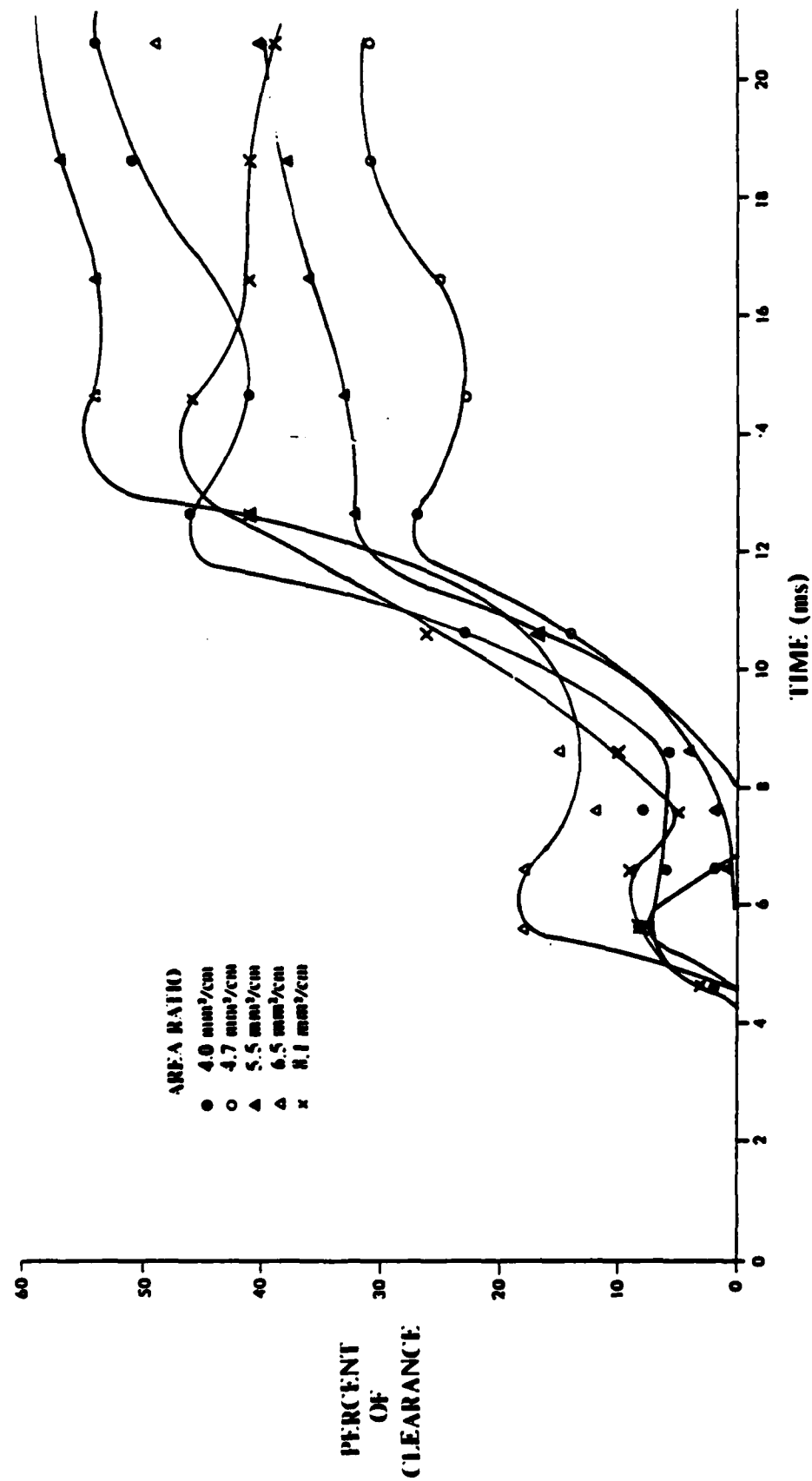


Figure 5. Film-Thickness as a Function of Time.

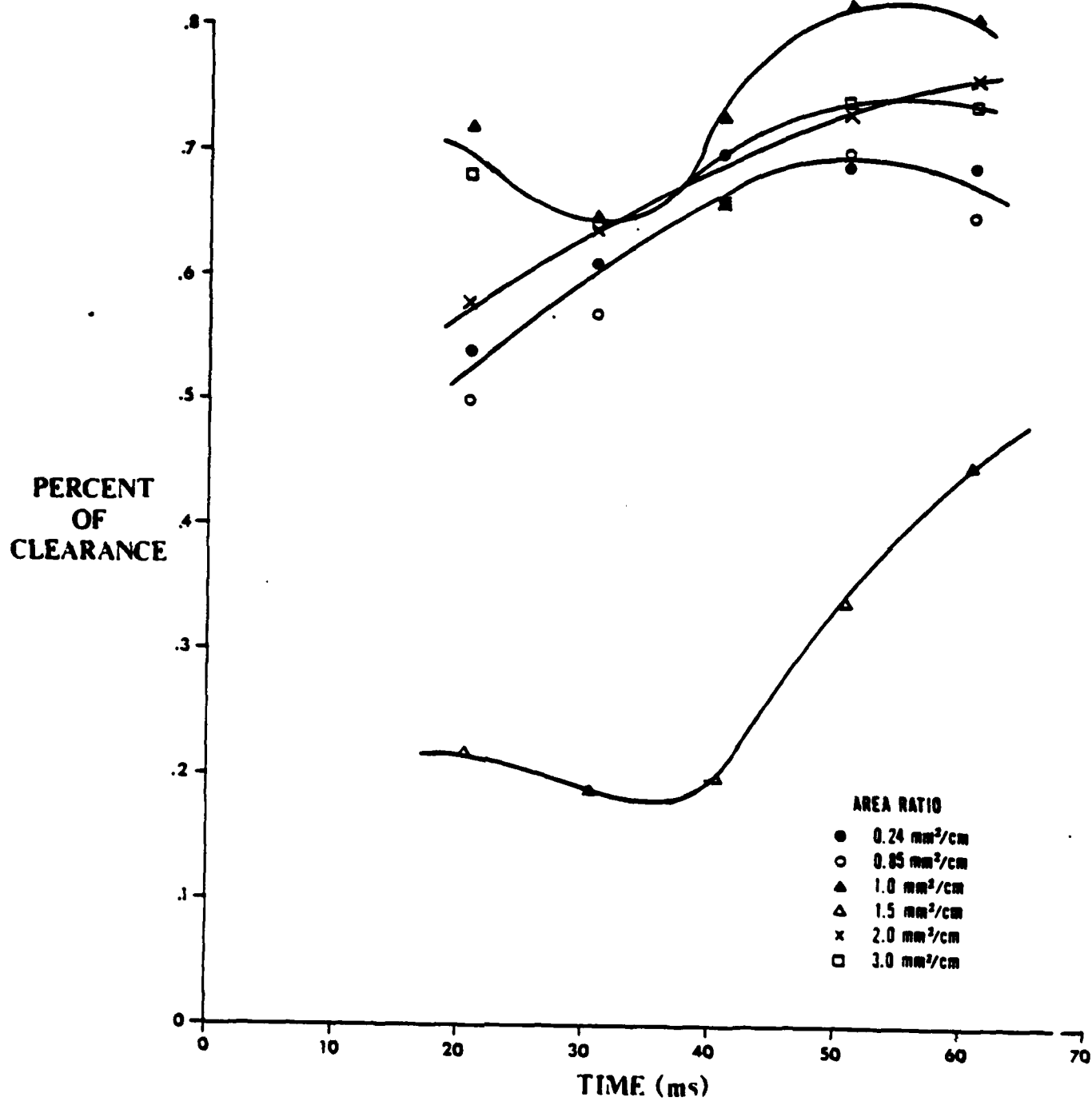


Figure 6. Film-Thickness as a Function of Time.

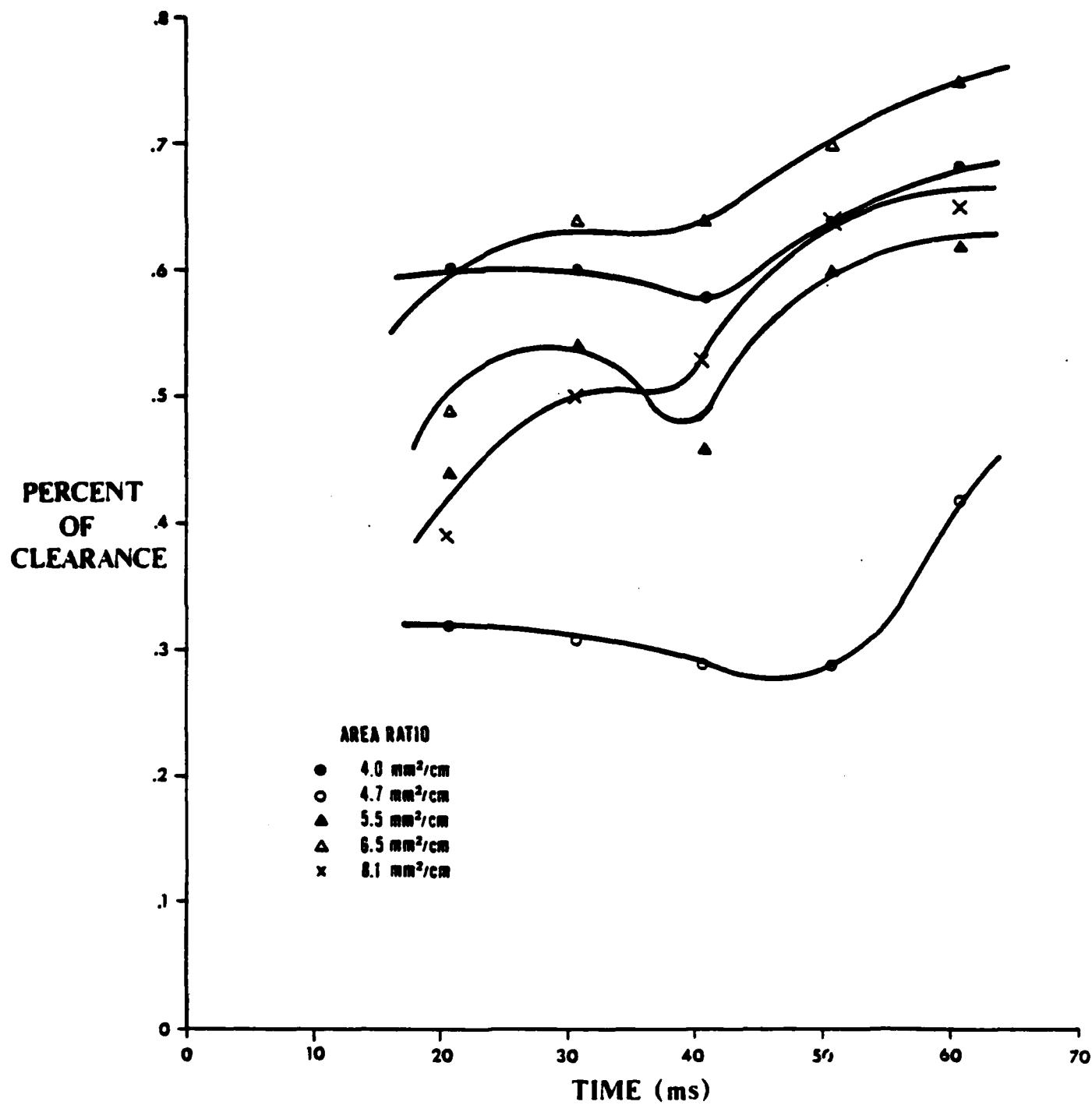


Figure 7. Film-Thickness as a Function of Time.

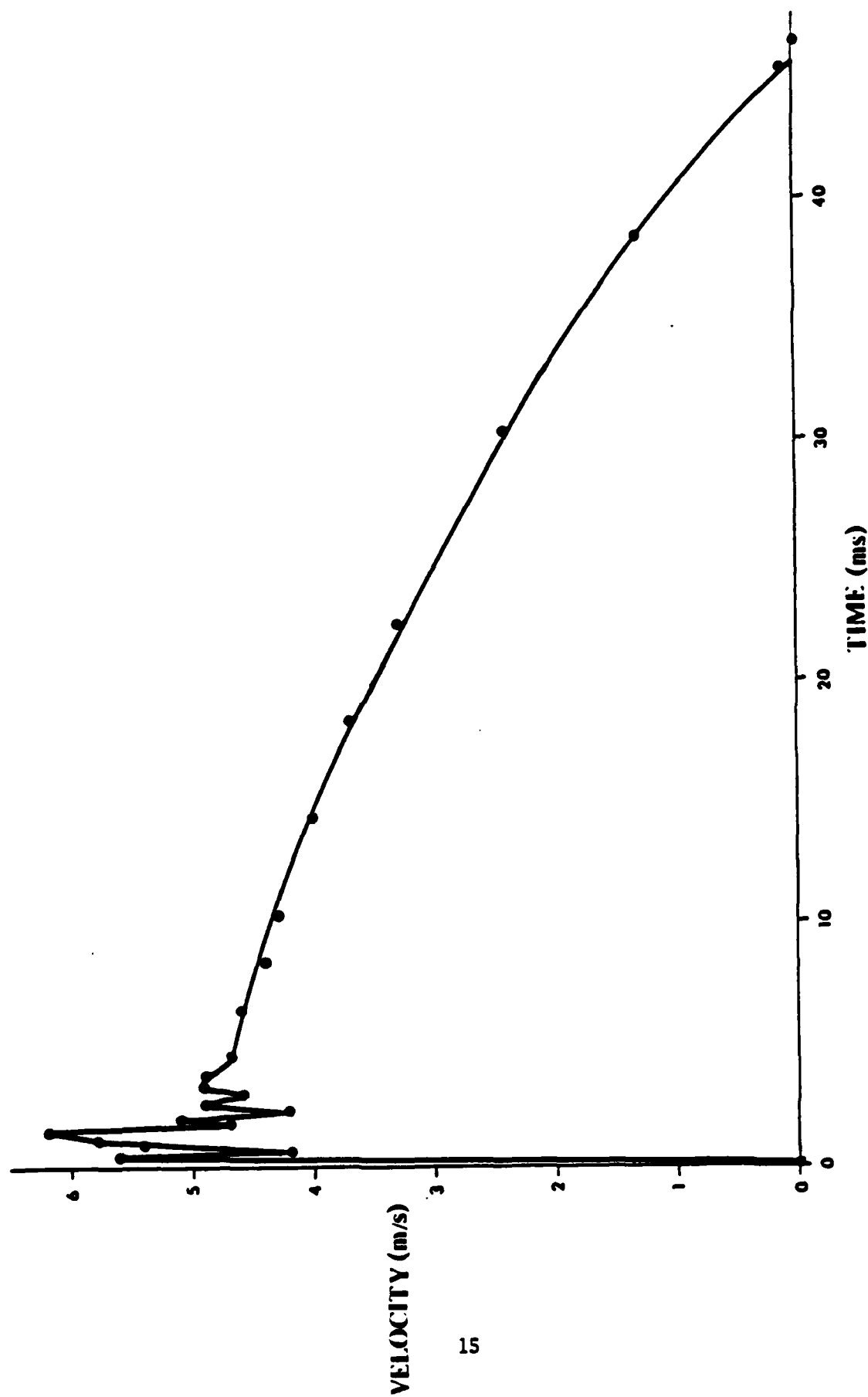


Figure 8. Velocity as Measured by LVDT Signal as a Function of Time.

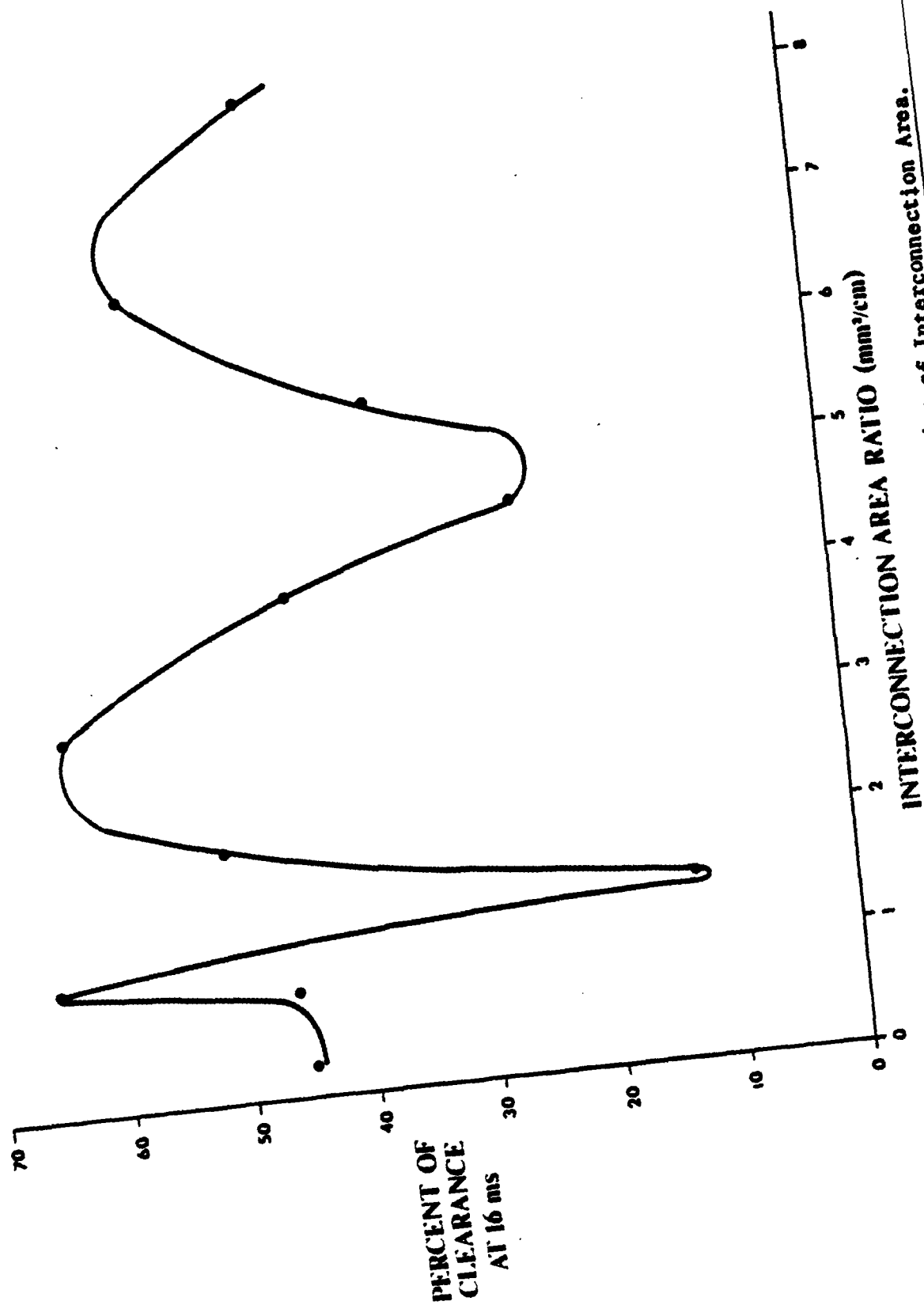


Figure 9. Film-Thickness at 16ms as a Function of Interconnection Area.

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